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EFFECT OF DEFOLIATION ON THE YIELD AND QUALITY OF 'PRATA COMUM' BANANA FRUITS[1]

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ABSTRACT - With the advent of black sigatoka in commercial banana crops in the "Vale do Ribeira" region, state of São Paulo, the monitoring the severity and chemical control of the disease in susceptible varieties have become more frequent in order to avoid leaf loss. This study simulated the effect of defoliation caused by the disease on the yield and quality of 'Prata Comum' banana fruits, depending on the formation period and fruit position in the bunch. The experimental design was completely randomized in a 2 x11 factorial scheme (period of bunch formation x number of leaves at flowering), 6-16 leaves at flowering in two periods of bunch formation with six replicates. In Period 1, flowering occurred at 04/15/13 and in Period 2 at 01/07/14, although in Period 1, bunch mass was higher and in Period 2, higher average maximum and minimum daily temperatures, precipitation and radiation were observed. Regardless of formation period, the number of leaves at flowering affected bunch mass, which ranged from 18 to 23 kg plant^{-1}. Defoliation affected the size of fruits of hand 1 and last hand of the bunch, but not the variability in fruit size due to the position the fruit occupies in the bunch and physicochemical characteristics.
Index terms: *Musa* sp., Sigatoka negra, bunch mass, fruit size, source/sink ratio.

EFEITO DA DESFOLHA NA PRODUÇÃO E NA QUALIDADE DOS FRUTOS DA BANANEIRA-'PRATA COMUM'

RESUMO - Com o advento da Sigatoka-negra nos bananais comerciais do Vale do Ribeira-SP, o monitoramento da severidade e o controle químico da doença em variedades suscetíveis passaram a ser mais frequentes, a fim de evitar a perda de folhas. Dessa forma, foi realizada a simulação da desfolha causada pela doença, com o objetivo de avaliar seu efeito na produção e na qualidade dos frutos da bananeira-'Prata Comum' (AAB), em função do período de formação e da posição da penca no cacho. O delineamento experimental foi o inteiramente casualizado, em esquema fatorial 2x11 (dois períodos de formação do cacho x número de folhas na floração (6 a 16), com seis repetições. No Período 1, a floração ocorreu em 15-04-13 e no Período 2, em 07-01-14. Apesar de, no Período 1, a massa do cacho ter sido mais elevada, no Período 2 observou-se temperaturas médias diárias máximas e mínimas, precipitação e radiação mais elevadas. Independentemente do período de formação, o número de folhas na floração afetou a massa do cacho, que variou de 18 a 23 kg planta^{-1}. A desfolha afetou o tamanho dos frutos da penca 1 e a última penca do cacho, mas não a variação de tamanho dos frutos em função da posição eles mesmo ocupam no cacho e as características físico-químicas.
Termos para indexação: *Musa* spp., Sigatoka negra, massa do cacho, tamanho do fruto, relação fonte/dreno.

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INTRODUCTION

In the southern coast of São Paulo, the "Vale do Ribeira" region has the largest planted area (36,000 ha) and banana production in the country (828,593 tons) (AGRIANUAL, 2016), with fruits of 'Prata' subgroup accounting for about 30% of the volume produced. With the advent of black Sigatoka in 2004 in the region caused by fungus *Mycosphaerella fijiensis Morelet*, severe foliar disease affecting photosynthesis, an intensification of management practices in susceptible varieties, such as the 'Prata Comum' cultivar (*Musa* sp. AAB) was observed (BENDINI et al., 2013), requiring more frequent sanitary defoliation and use of fungicides.

The elimination of leaves with more than 50% of their area damaged by black and necrotic spots or in the process of senescence and petiole collapse is recommended, contributing to reduce the fungus inoculum source (NOMURA et al., 2015).

Studies carried out in several regions of the world have shown the need for at least 7 (RAMÍREZ et al., 2008), 7 to 9 (VARGAS et al., 2009) and up to 12 (GONZÁLEZ et al., 2012) functional and healthy leaves at the time of flowering for the adequate filling of fruits in bunches of Cavendish banana trees. According to the most recent study, for 'Prata ' subgroup, 10 to 12 functional leaves are required in flowering to guarantee crop production (RODRIGUES et al., 2009).

In the presence of black Sigatoka under conditions of the "Vale do Ribeira" region, SP, studies aimed at determining the number of leaves required at the moment of flowering to guarantee the quantity and quality of production have not yet been carried out. Moreover, the effect of sanitary defoliation on fruit size variation as a function of the position occupied within the bunch, which according to Jullien et al. (2001), in banana fruits of the Cavendish subgroup, is of the order of 30-40% and compromises marketing.

Thus, this study aimed to determine the effect of defoliation on the production and quality of 'Prata Comum' banana fruits under the climatic conditions of the "Vale do Ribeira" region, SP, according to two periods of bunch formation and position of the fruit in the bunch.

MATERIAL AND METHODS

The study was carried out in a five-year-old commercial production area with density of 1,111 plants ha^{-1} located in the city of Registro, on the banks of the Ribeira de Iguape River, "Vale do Ribeira" region, SP (24º 28 '17 " S, 47 ° 50 '39 "W, 20m a.s.l.). The experimental area was lowland with typical clayey Oxissol Hapludox soil, and humid tropical climate (Af), according to Köppen classification.

'Prata Comum' (*Musa* sp. AAB) banana trees from clumps or families that received all the cultural practices recommended for banana cultivation were used. The chemical control of black Sigatoka was performed based on the weekly monitoring of disease severity based on the method described by Fourè (1988), adjusted by Moraes et al. (2005).

The experimental design was a completely randomized design, in 2 x11 factorial scheme (two periods of bunch formation x number of leaves at flowering), adopting treatments with 6 to 16 leaves at flowering in two formation periods with six replicates. In Period 1, flowering occurred on 04/15/2013 and in Period 2 on 01/07/2014, and the meteorological data were daily recorded (Table 1).

The size of fruits was evaluated according to their position in the bunch, adopting a completely randomized design in a factorial scheme and subdivided plot, being the 2 x 11 factorial in the plot, and in the subplot, the proximal (hand 1), medium (hand 4) and distal (last hand) positions of the bunch. Defoliation was carried out manually, removing older and young leaves, thus simulating the natural defoliation caused by black Sigatoka. Functional leaf was considered one with more than 50% of blade without typical symptoms of the disease or yellowing due to senescence.

Harvest was performed when fruits of the last hand of the bunch reached 30 mm in diameter. The mass of the bunch and stalk, number of hands per bunch, in addition to the mass, number, diameter and average length of fruits of hand 1, hand 4 and last hand of each bunch were all determined. The mass of hands and bunches was evaluated in digital scale, while the length and the diameter of the fruit, respectively, were evaluated with tape measure and digital caliper. The fourth hand was stored in a chamber at 25°C without ethylene treatment until the complete maturation of fruits or when the peel color was completely yellow, corresponding to stage 6 of the Von Loesecke scale (1950). At this moment, the postharvest period of fruits, mass loss, peel color, firmness, soluble solids content, pH and titratable acidity were determined.

The post-harvest period corresponded to the number of days needed for the fruit to reach full maturation. The bark color was estimated in Minolta CR400 colorimeter, and color was expressed in three variables: L, corresponding to luminosity (0 = dark / opaque and 100 = white); *C*, chromaticity

(0 = impure color and 60 = pure color); and H, the hue angle (0°=red, 90°=yellow, 180°=green, 270°= blue and 360°=black).The pH was estimated in a digital pH meter with ceramic electrode after pulp homogenization with water according to AOAC (1997), followed by titratable acidity, after titration with 0.1N NaOH in the presence of phenolphthalein. Soluble solids content was determined in a portable digital refractometer, after pulp homogenization with water, according to Tressler and Joslyn (1961). Firmness was estimated with a portable analogue penetrometer and tip of 0.8cm after removal of the fruit bark. Analyses of all physicochemical characteristics were performed in three replicates.

The results were submitted to analysis of variance and, when significant by the F test, the means of treatments submitted to the Tukey test or regression study by orthogonal polynomials. The number of leaves and the mass of bunch were correlated using the Pearson method.

RESULTS AND DISCUSSION

Except for the pseudostem perimeter at harvest and the number of fruits of hand 1, the other vegetative and productive characteristics evaluated were higher in Period 1 (Table 2), showing higher plant growth. However, in Period 2, mean maximum and minimum daily temperatures, precipitation and radiation were recorded at 4.56 and 4.04°C, 186.42 mm and 5.42 MJ m^{-2}, respectively (Table 1).

Temperatures <14°C and >30°C, unsuitable for banana growth (RAMIREZ, 2011), occurred in the two periods; however, with a marked difference in their frequency (Table 1). The lowest temperatures occurred between early evening and early morning, while the highest temperatures occurred at higher radiation times, a more frequent condition in Period 2. According to Donato et al. (2013) under supra-optimal temperature, even with adequate irrigation water, the photosynthesis of banana plant can be affected, a condition that may explain the lower bunch mass in Period 2, despite the greater water availability. Lower temperatures tend to reduce the speed of metabolic reactions and the filling rate, increasing the number of days between flowering and bunch harvesting, as in Period 1.

There was no difference in the number of hands in the bunch between periods, whose mean value was 10.14; therefore, the difference in bunch mass was due to differences in the mass of stalk and hands, resulting from variations in the number and size of fruits (Table 2).

The perimeter of the pseudostem at harvest was affected by the number of leaves at flowering, proportionally increasing with the increase in the number of leaves (Figure 1A), which was expected, since it is composed of leaf sheaths. The number of leaves at harvest was the only variable influenced by the interaction between the period of bunch formation and the number of leaves at flowering, with a linear response in both periods, but higher in Period 1 (Figure 1B).

Regardless of number of leaves kept at flowering, at harvest, plants in Period 1 had from one to five leaves less than plants of Period 2. This result shows seasonality in leaf area duration, which may be related to water availability (Table 1) and with the mobilization of nutrients to the bunch or to other plant parts. Ramírez et al. (2008) evaluated the impact of defoliation on the ‘Grande Naine’ variety with black Sigatoka and observed that maintaining 7, 9, 11 or all leaves in the plant at the moment of flowering, in plants that had 13 to 14 leaves, 6 to 7 leaves were quantified at harvest.

The number of leaves at flowering influenced bunch mass, regardless of period (Figure 1C). The linear response suggests that the remaining leaves did not increase the photosynthetic rate to compensate for the lost leaf area. It also indicates that under higher radiation availability (Period 2), there was no impact on photosynthesis by shading. There was a correlation between bunch mass and number of leaves at harvest in Period 1 ($Y=13.39+0.66x^{**}$ $R^2=0.55^{**}$, $r=0.74^{**}$) and Period 2 ($Y=10.52+1.48x^{**}$, $R^2=0.81^{**}$, $r=0.90^{**}$), indicating the leaf as the main source of photoassimilates. In Period 1, the time of hand formation was 203 days, with a quadratic response as a function of the number of leaves at flowering (Figure 1D), whereas in Period 2, time was 160 days, not allowing adjusting the regression equation.

Mass of hand 1, diameter of fruit in hand 1 and fruit length in the last hand were affected by the number of leaves, presenting a linear response, while fruit length in hand 1 showed a quadratic response, increasing up to 14 leaves (Figures 1E, 1F, 1D and 1H). Chillet et al. (2006) also observed that fruit length was the variable most affected by defoliation, which in the present study, it was observed in the first and last hand of the bunch. The reduction in fruit size with leaf removal (CHILLET et al., 2006) or shading (JULLIEN et al., 2001) was associated with decreased cell division or filling rate. Such an effect on fruit diameter can be minimized by increasing the time of hand formation.

The fact that defoliation promotes reduction in the size only of fruits of hand 1 and the last hand of the bunch (Figures 1F, 1G and 1H) is related to stage of development of fruits at the time of defoliation. Fruits of hand 1 probably showed higher growth rate, which promoted greater impact. As there is a delay in the development of fruits of hand 4 in relation to hand 1, the plant was able to recover the flow of assimilates, in such a way that defoliation did not affect the size of the fruits of hand 4. The growth of fruits of the last hand occurred with additional limitation of photoassimilates due to defoliation, resulting in shorter fruits, but with minimum diameter, as they reached the established harvest point. Vargas et al. (2008, 2009); González et al. (2012) reported that defoliation at flowering did not influence the mass of hands or the size of "Grande Naine' fruits under in tropical conditions, suggesting different effects in other varieties and climatic conditions.

The triple interaction between the period of bunch formation, number of leaves at flowering and position of the hand in the bunch was significant for the hand mass, but not for the number and size of fruits. This means that the variability in length and diameter of fruits as a function of the position occupied in the hand was not influenced by defoliation. The triple interaction showed that only the mass of hand 1 differed between plants maintained with different number of leaves when formed in Period 1, with linear response ($Y = 1.19+0.09x^*$ $R^2 = 0.54^*$).

Regarding the variation of fruit size as a function of the position of the hand in the bunch, there was a reduction of 14.68 and 25.81% between the mass of hand 1 in relation to hand 4, and of hand 4 in relation to the last hand of the bunch In Period 1, and 17.88 and 21.77% in Period 2, respectively (Figure 2A). For hands in any position, the mass in Period 1 was higher than in Period 2, agreeing with the greatest hand mass.

The number of fruits per hand decreased along the bunch, a variable that was defined before inflorescence emission, that is, it could not be influenced by defoliation, which also did not differ between periods for any bunch position (Figure 2B). Fruit length decreased from hand 1 to the last hand in the bunch in Period 1, and from hands 1 and 4 when compared to the last hand in Period 2 (Figure 2C).

Fruit diameter was influenced by the position in bunches formed in Period 1 (Figure 2D), which a variable related to the number of cells along the radius and filling rate (JULLIEN et al., 2001). The absence of variability in Period 2 indicates that the availability of photoassimilates was the same, despite the age difference among fruits, probably due to the greater radiation availability (Table 1).

There was no influence of the defoliation on the postharvest period and on the physicochemical variables, color, firmness, soluble solids content and titratable acidity (Table 3), which shows that there was no influence on fruit composition and ripening, as described by Calvo and Bolaños, (2001), Barrera et al. (2009) and Ramírez et al. (2008). Luminosity was not influenced by the period of bunch formation; however, postharvest period and chromaticity were higher in Period 2, whereas hue angle, firmness, soluble solids content and titratable acidity were higher in Period 1 (Table 3).

Rodrigues et al. (2009) determined the effect of defoliation on 'Prata-Anã' variety in Janáuba, MG, maintaining 4, 6, 8, 10, 12 or 14 leaves at flowering, obtaining bunch mass ranging from 15.54 to 29.44 Kg $plant^{-1}$. They estimated the need of 10 to 12 leaves at flowering for good yield, under irrigation and density of 1,234 ha^{-1} plants. Under this condition, plants probably had higher radiation availability and absence of black Sigatoka symptoms, which justifies the lower bunch mass obtained in this study (Figure 2C).

Rodrigues et al. (2009) suggested the maintenance of at least 10 leaves to allow the production of 19.04 kg $plant^{-1}$ (Figure 1C), that is, 21.15 tons ha^{-1}, being above the average yield obtained in São Paulo in 2015, which was 14.57 tons ha^{-1} (IBGE, 2016). The intensification of chemical control is also suggested, restricting defoliation to non-functional leaves, which are the main source of fungus inoculum.

TABLE 1- Climatic conditions in the period of bunch formation of 'Prata Comum' banana tree.

Year	Daily T min °C	Daily T max °C	T<14°C nº days	T >30°C nº days	Precipitation mm	Total radiation MJ m^{-2}	Average relative humidity %
Period 1	14.70	24.44	55	19	523.02	20.54	79.67
Period 2	19.26	28.48	11	70	709.44	25.96	77.72

Period 1: 04/15/13 to 10/14/13; Period 2: 01/07/14 to 07/14/14.

TABLE 2- Perimeter of pseudostem at harvest (PPharv), plant height at harvest (PHharv) and number of leaves at harvest (NLharv), bunch filling time (BFT), bunch mass (BM), stalk mass (SM), mass of hand 1 (MH1), number of fruits of hand 1 (NFH1), length (LFH1) and diameter of fruits of hand 1 (DFH1), mass of hand 4 (MH4), number of fruits of hand 1 (NFH4), length (LFH4) and diameter of fruits of hand 4 (DFH4), mass of last hand (MLH), number of fruits of last hand (NFLH), length (LFLH) and diameter of fruits of last hand (DFLH), as a function of the period of formation of the 'Prata Comum' banana bunch.

	PPharv cm	**PHharv cm**	**NLharv**	**BFT day**	**BM kg**	**SM kg**
Period 1	86.32 B	4.13 A	9.24 A	201.06 A	22.61A	3.14 A
Period 2	123.78 A	3.97 B	6.04 B	157.34 B	16.01B	2.41 B
Mean	105.33	4.05	7.70	180.04	19.44	2.79
vc (%)	5.42	6.40	9.22	9.58	15.98	19.37
F	1139.70**	9.14**	151.14**	2.12*	117.32**	46.76**

	MH1 kg	**NFH1**	**LFH1 cm**	**DFH1 mm**	**MH4 kg**	**NFH4**
Period 1	2.18 A	19.20 B	19.74 A	33.94 A	1.86 A	17.75 A
Period 2	1.50 B	20.84 A	16.82 B	29.52 B	1.24 B	16.86 B
Mean	1.86	19.99	18.33	31.82	1.56	17.32
vc (%)	23.46	20.38	8.68	7.84	15.77	6.56
F	62.76**	4.19*	87.43**	81.35**	131.21**	16.41**

	LFH4 cm	**DFH4 mm**	**MLH kg**	**NFLH**	**LFLH cm**	**DFLH mm**
Period 1	18.64 A	33.28 A	1.37 A	16.12 A	16.29 A	32.64 A
Period 2	16.13 B	29.44 B	0.97 B	15.36 B	14.86 B	29.68 B
Mean	17.43	31.44	1.18	15.75	15.60	31.22
vc (%)	7.54	7.97	6.98	6.23	6.50	5.90
F	95.18**	81.35**	105.63**	15.92**	52.10**	2.59*

Period 1: 04/15/13 to 10/14/13; Period 2: 01/07/14 to 07/14/14.
Means followed by different letters in the same column, do differ from each other, by the Tukey's test p<0.05.
**, p<0.01; *, p<0.05; ^{NS}, not significant by F test; VC, variation coefficient.

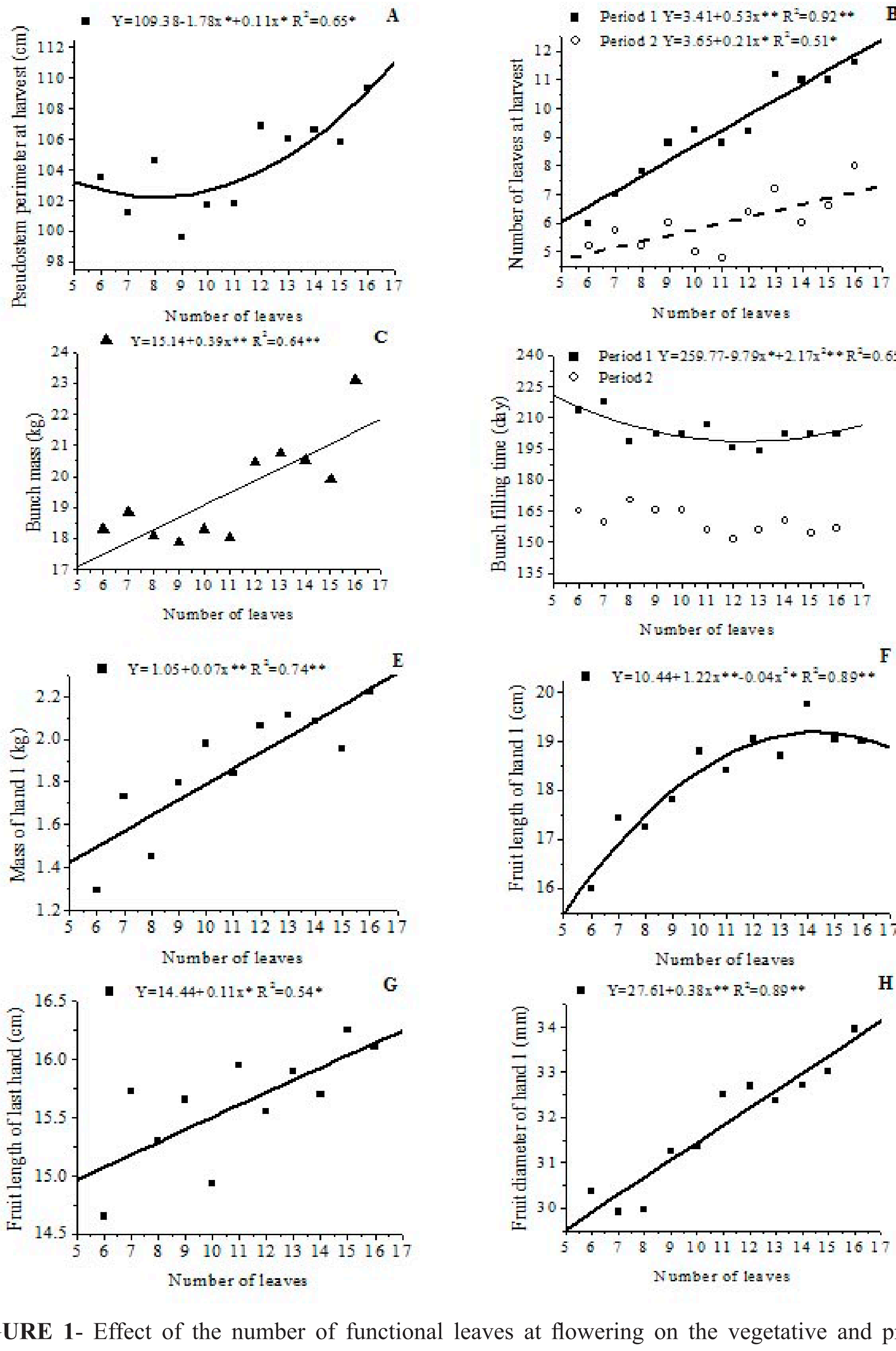

FIGURE 1- Effect of the number of functional leaves at flowering on the vegetative and productive characteristics of 'Prata Comum' banana tree.

Period 1: 04/15/13 to 10/14/13; Period 2: 01/07/14 to 07/14/14.
*, $p < 0.05$; **, $p < 0.01$, probability by T test; R2, coefficient of determination.

TABLE 3 - Postharvest period (PP), luminosity (L), hue angle (h°), chromaticity (C), firmness (F), total soluble solids (TSS) and titratable acidity (TA) as a function of period of bunch formation of 'Prata Comum' banana.

	PP day	L	h°	C	FN	TSS °Brix	TA % ac. malic
Períod 1	10.01 B	73.39	88.88 A	53.54 B	14.95 A	15.52 A	0.73 A
Períod 2	12.38 A	73.73	89.78 B	55.12 A	11.34 B	13.20 B	0.62 B
Mean	11.15	73.55	89.32	54.30	11.35	14.40	0.68
vc (%)	44.72	3.95	1.40	7.36	8.53	6.24	8.25
F	5.81*	0.35^{NS}	13.46	4.05*	1391.02**	12.63**	104.26**

Period 1: 04/15/13 to 10/14/13; Period 2: 01/07/14 to 07/14/14.
Means followed by different letters in the same column, do differ from each other, by the Tukey's test p<0.05.
**, p<0.01; *, p<0.05; ^{NS}, not significant by F test; VC, variation coefficient.

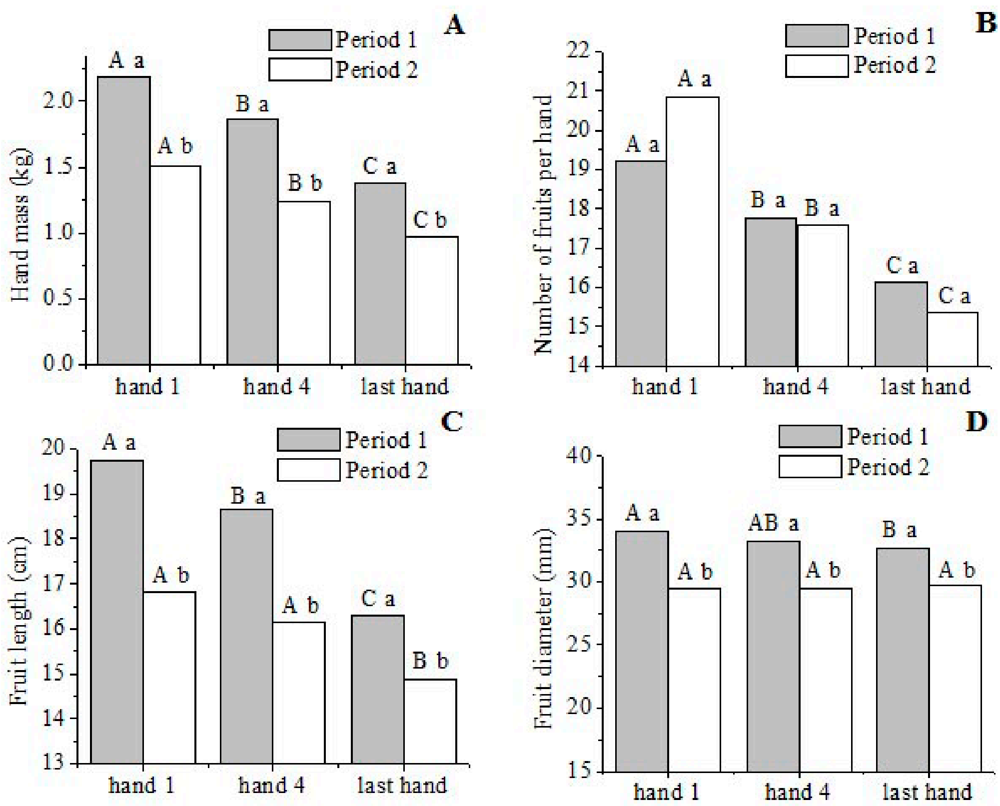

FIGURE 2 - Effect of the period of bunch formation and hand position in the bunch on the productive characteristics of 'Prata Comum' banana tree.

Period 1: 04/15/13 to 10/14/13; Period 2: 01/07/14 to 07/14/14.
Means followed by different, upper case letters for hand position in the bunch and lowercase for period of bunch formation, differ by Tukey test at p<0.05

CONCLUSION

Regardless of period, the production and size of “Prata Comum” banana fruits decreases with the reduction in the number of functional leaves at flowering, without modification of the size variation among fruits of different position in the bunch and physicochemical characteristics.

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